PB-242 588

FTP/SHORT CYCLE CORRELATION TESTING FOR 207 (b) IMPLEMENTATION - CATALYST EQUIPPED VEHICLES. VOLUME I

J. A. Gunderson

Olson Laboratories, Incorporated

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Environmental Protection Agency

April 1975

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FTP/SHORT CYCLE CORRELATION TESTING FOR 207 (b) IMPLEMENTATION - CATALYST EQUIPPED VEHICLES VOLUME 1

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Report contains emission data collected by the Federal Test Procedure and five short tests. The vehicles tested were catalyst equipped prototype cars loaned to EPA by the Ford Motor Company.

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April 1975

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A P P E N D I X E S (Volume II)

A Emission Test Results

B Test Fuel Analysis

C Analyzer Calibration Curves

D CVS Calibration Curve

E Dynamometer Calibration Curves

F Ford Catalyst Test Vehicle Maintenance History

Section 1

INTRODUCTION AND SUMMARY

The objective of the work performed under this contract was to provide test data leading to the identification of which of five existing short-cycle emissions tests is most capable of being "correlated" with the Federal Test Procedure (FTP) as used for the certification of 1975 model year and later light-duty vehicles. The FTP is described in detail in the Federal Register, Volume 37, Number 221, Section 85.075-9 through Section 85.075-26. The five short-cycle emission tests are:

1. Clayton Key Mode - Volumetric Procedure

2. Federal Three-Mode - Volumetric Procedure

3. Unloaded Test, High Speed (2,500 rpm) and Idle (Derived from 1 and 2) - Volumetric Procedure

4. Federal Short Cycle (9-Mode) - CVS Procedure

5. Composite N.J. ACID/N.Y. Short Test - CVS Procedure

All testing was performed at the Olson Laboratories' facility, Anaheim, California.

Fifty-eight catalyst equipped experimental vehicles owned by the Ford Motor Company and located at Pico Rivera, California, were tested in the program through December. In January and February, ten additional test series were performed. Five of these vehicles, owned by the State of California, are former Ford Motor Company experimental vehicles in the same configuration as all others in this test program. The other five test series were performed on two previously untested vehicles in the first fleet of fifty and on three vehicles that had been previously tested, but whose tests were invalid. All of the vehicles were loaned to EPA and Olson for the duration of testing.

The Ford Motor Company representative who supported this test program is:

M. G. "Pete" Noll
Catalyst Task Force Leader
8900 East Washington Boulevard
Pico Rivera, California 90666
(213) 949-3470 or (800) 352-8979

Alternate

John Sundstrom
Engine Division, Engineer
Same address and telephone number

The Catalyst Task Force was transferred to Dearborn, Michigan in December 1974.

All vehicles tested met the EPA definition of a light-duty vehicle and were standard size (Class IV). Each vehicle was identified by an eight-character code using four characters for Ford's ID code, a 4 for Class IV, a 1 for Group I and a two-digit car number from 01 to 70. All vehicles were Ford Galaxie, Four-door sedans, equipped as follows:

400 cubic inch displacement V-8
2-venturii carburetor
Exhaust control system types
    Air injection
    Catalytic reactor
    Exhaust gas recirculation
Canister-type evaporative system
Automatic transmission (C-6)
3.0-to-1 rear axle ratio
HR78 x 15 radial ply tires
Air conditioning
Power steering
Power brakes

Forty-eight vehicles were tested in the initially scheduled group of tests ending 30 October 1974. Due to undetected instrumentation problems, many of these tests were found to be invalid. The problem was not identified until after these tests were completed. Ten additional vehicles were tested (after correcting the instrument problems) from 11 December to 16 December 1974, with ten more test series completed on seven untested and three previously tested vehicles from 22 January to 19 February 1975.

A computer listing of the accepted test data is given, in Olson identification number order (4101 to 4170), in Appendix A. Two vehicles, T2544141 and T1/54149, were not tested in the first test group due to time constraints. They were tested with the January group.

These two vehicles, along with three other vehicles, are being held at Olson-Anaheim for additional testing under Task Order 05. The vehicles being retained are:

Ford ID	Initial Olson ID	New Olson ID	Task Order 02 Final Mileage
T254	4141	4169	11,432
T236	4142	4165	9,975
T161	4144	4170	25,117
T175	4149	4162	9,120
T210	4150	4164	23,307

An initial group of six vehicles was acquired from Ford. As each vehicle test was completed, it was exchanged at the Ford Pico Rivera plant on a one-for one basis.

The vehicles were tested using Indolene Clear fuel. The as-received tank fuel was drained completely and the tank was then filled to approximately 80 percent of tank volume with the test fuel. Each vehicle was run for approximately 10 minutes to replace the fuel in the fuel lines and carburetor.

As-received engine parameters were measured and recorded. The first 48 vehicles were pre-conditioned by running through the short test sequence defined in section 2.3. The remaining vehicles were pre-conditioned using the LA-4 driving cycle. This was followed by an FTP Cold Soak prior to the FTP emissions test. The sequence of events for each vehicle is shown in Figure 1-1. After completion of both 1975 FTP tests on a given vehicle, the results were compared to ensure that the deviation from the mean for HC, CO, or NO_x was less than 15 percent for any one pollutant. If it was greater than 15 percent, the Project Officer was queried about a retest before returning the vehicle to Ford.

An additional FTP and Short Sequence test was authorized on the following vehicles:

Ford ID	Olson ID
T243	4103
T048	4104
T173	4113

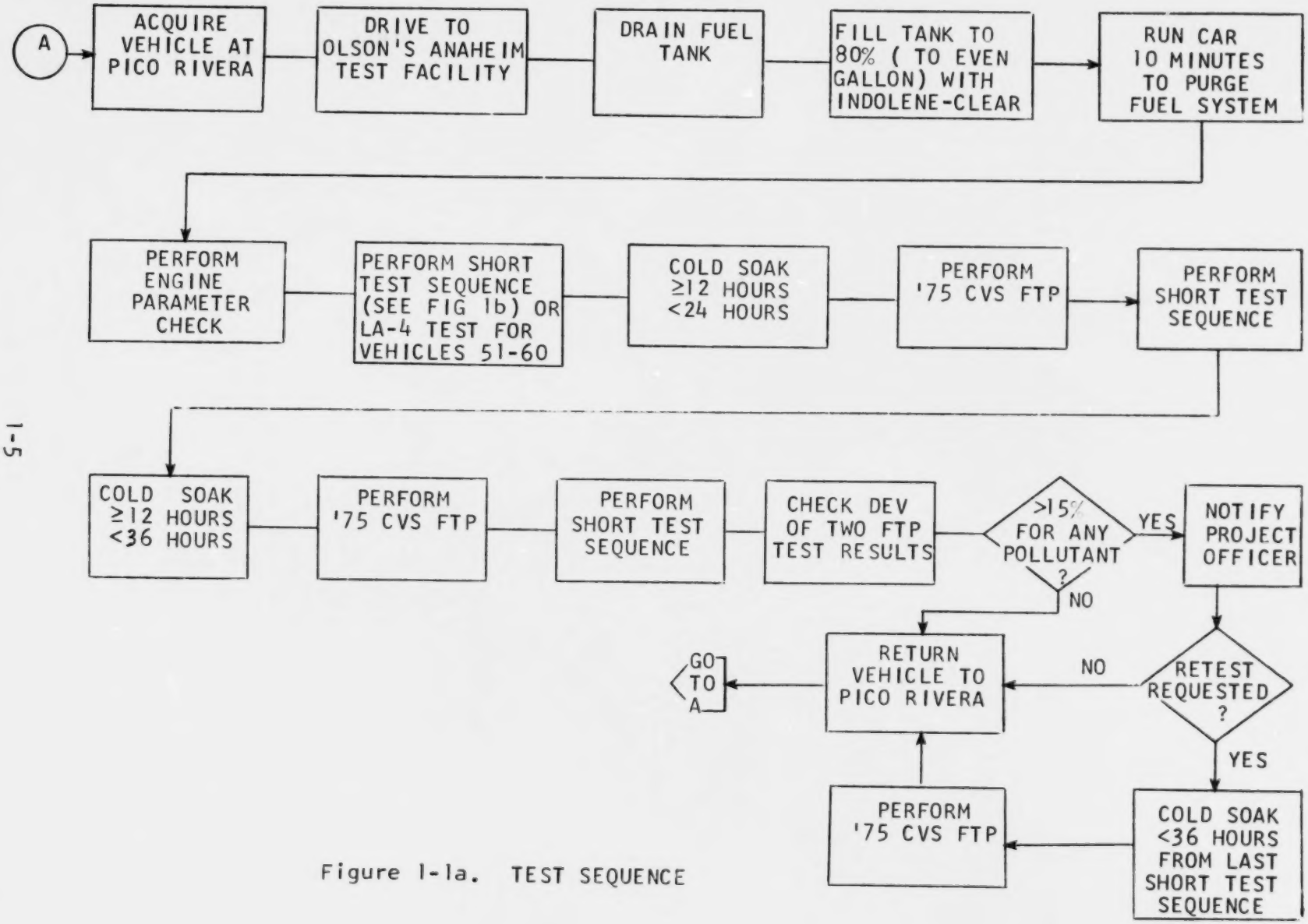

Figure 1-1a. TEST SEQUENCE

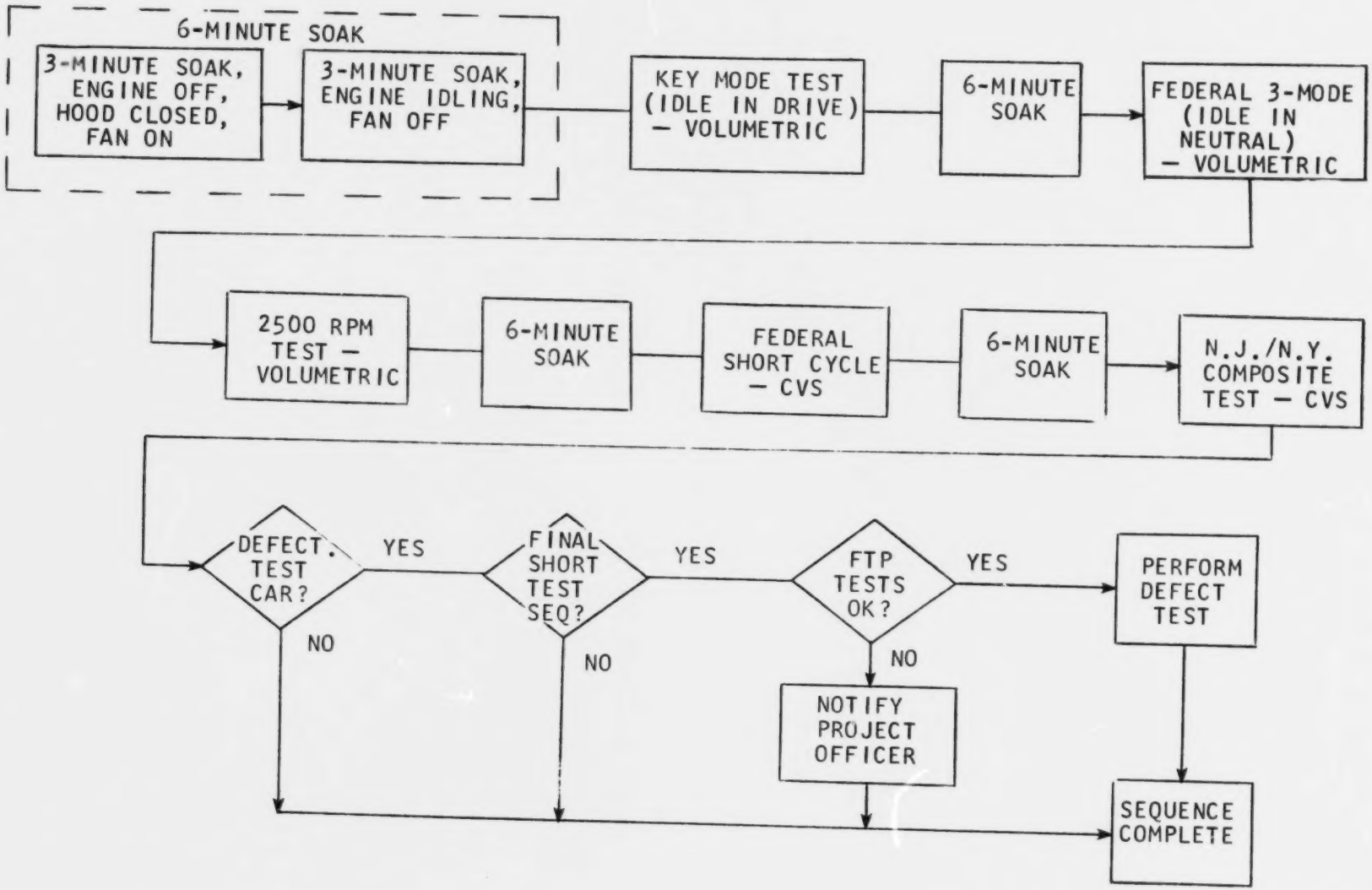

Figure 1-1b. TEST SEQUENCE — SHORT

Section 2

TEST PROCEDURE

2.1 GENERAL

Many of the vehicles used in this program had been in storage for some time. Prior to the loan of these vehicles for testing, the Ford Motor Company prepared each one in the following manner. Vehicles that had not been operated recently were driven approximately 100 miles and then given a complete engine diagnosis. Timing and idle speed were set to specification, and the air pump belt tension and catalyst over-temperature sensing systems were checked. Corrections were made where necessary.

Upon receipt at Olson, each vehicle was given a distinct identification number which permits identification as to class, group and number within the group. The first four characters use Ford's identifying number, while the last four digits are Olson's identifying number. The test results identify the source vehicle and the number of the test on that vehicle.

2.2 FUEL

All vehicles were tested with Indolene Clear fuel, inspected in accordance with 37 Federal Register 221,

Section 85.073-10 and SAE Technical Report J171, paragraph 2.1. Each batch of fuel used in the program was analyzed as reported in Appendix B.

2.3 TESTING SEQUENCE

The following procedure applies to all vehicles tested under this program, unless otherwise noted (also see Figure 1-1a). The as-received fuel was drained from the vehicle tank following vehicle receipt. The gas tank was then filled to approximately 80 percent capacity (to the nearest gallon) with the test fuel. The vehicle was then operated either on the street or on a dynamometer for approximately ten (10) minutes to both purge the fuel system of as-received fuel and to prepare the vehicle for the as-received, state-of-tune inspection. Upon completion of the 10 minute operating period, the vehicle was inspected to determine its as-received state-of-tune. The results of this inspection were then recorded on the form shown in Figure 2-1. Following the vehicle engine parameter inspection, a vehicle preconditioning was performed consisting of one short test sequence (emissions being recorded on the forms shown in Figures 2-2 and 2-3). The preconditioning for the vehicles tested in December, January and February consisted of one LA-4 driving cycle with no collection of emissions data. The vehicles were then cold-soaked in preparation for emissions testing in accordance with the Federal Test Procedure (vehicle fueling and fuel heating excluded).

The FTP was then run after at least a 12-hour soak but less than 24 hours. Following the FTP emissions test, the vehicle was tested in accordance with the short test sequence. This short test sequence constituted the

Olson Laboratories, Inc. Testing Services Division

1 A CARD | 11 MO | 13 DAY | 15 YR | 18 MFG | 22 YR | 25 MAKE/MODEL
33 SERIAL NUMBER | 46 ST | 48 LICENSE NUMBER
56 CYL | 57 CID | 60 BBL | 62 EXHAUST CONTROLS | 71 EVP | 73 VEHICLE NO.

CUSTOMER

Name _____ Address _____

City _____ State _____ Zip _____

Phone _____ Comments _____

SCHEDULING

Date _____ Time _____ Scheduled By _____

Directions: _____

1 B | 11 MO | 13 DAY | 15 YR | 18 A/C | 20 P/S | 22 P/B | 24 TR | 26 TR TYPE | 30 AXLE | 35 TIRE SIZE
45 ODOMETER | 52 DWELL | 57 TIMING | 62 RPM | 66 CO.% | 73 VEHICLE NO.

PERFORMANCE SCHEDULE

Ready for Inspection ☐

Pre-Inspection Complete — Accept ☐ Reject ☐

Mechanic _____

1st Test Complete ☐

Run No. _____

Cold Soak Time In _____ Time Out _____

2nd Test Complete ☐

Run No. _____

Cold Soak Time In _____ Time Out _____

3rd Test Complete ☐

Run No. _____ ☐

Car Returned _____ ☐
DATE/TIME

VEHICLE INSPECTION

	OK	Bad	COMMENTS
1] Oil Level	☐	☐	
2] Radiator Level	☐	☐	
3] Condition of Hoses	☐	☐	
4] Transmission Level	☐	☐	
5] PCV Valve	☐	☐	
6] Ignition Wires	☐	☐	
7] Belts	☐	☐	
8] Tires	☐	☐	
9] Exhaust System	☐	☐	
10] Brakes	☐	☐	
11] Air Cleaner	☐	☐	
12] Other _____	☐	☐	

Figure 2-1

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Olson Laboratories, Inc. Testing Services Division

Figure 2-2

744067-2

Olson Laboratories, Inc. Testing Services Division

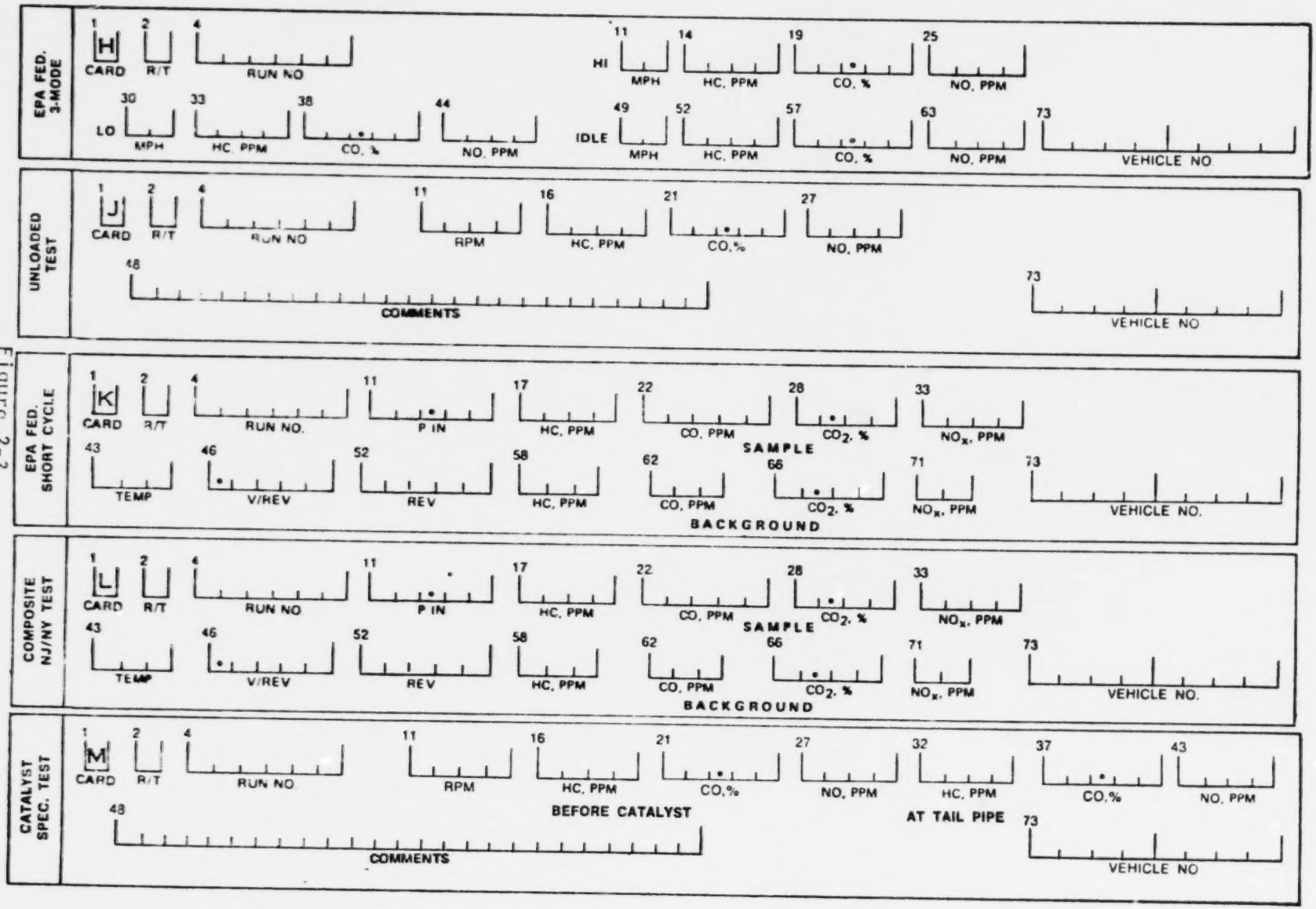

Figure 2-3

744067-3

vehicle preconditioning for the second FTP emissions test on the vehicle. Following the completion of the second FTP on the vehicle, another short test sequence was performed.

Before returning the completed vehicle to Ford, the two FTP emissions tests were checked to ensure that the results were repeated to within 15 percent of the mean for each pollutant. If this criterion was not met, the EPA Project Officer was notified, at which time he had the option to verbally request that one additional FTP emissions test be performed. In no case was the cold soak following the second or third short test sequence to be allowed to exceed 36 hours before performing the subsequent FTP. This required a preconditioning rerun of the short test sequence (without data recording) in some cases.

One vehicle (T0264118) was returned to Ford; and it was subsequently found that the soak periods between major test sequences had exceeded the maximum of 24 hours prior to the first FTP and 36 hours prior to the second FTP. The vehicle was returned to Olson for a complete retest. The test results of this second group of tests were reported.

2.3.1 Short Test Sequence

The short test sequence consists of the following tests and soak periods in the order shown (also see Figure 1b):

1) Soak - 6 minutes
2) Clayton Key Mode (Idle in drive)
3) Soak - 6 minutes
4) Federal Three-Mode (Idle in neutral)
5) High-Speed Unloaded Test (2500 rpm)

6) Soak - 6 minutes

7) Federal Short-Cycle

8) Soak - 6 minutes

9) New Jersey/New York Composite Cycle

10) Defect Test for specific vehicles during final short test sequence

Mass analysis of the exhaust samples taken during the Federal Short-Cycle and NJ/NY Composite Cycle was found to be difficult due to the small sample volume obtained. In many cases, the volume was depleted before analyzer stabilization could be obtained. To solve this problem, two tests were run, one-after-another, for each of the two cycles for the last 20 vehicles tested, with the result that twice the volume was collected over twice the cycle driving distance. These factors-of-two cancel in the mass calculation. The doubled volume was found to be sufficient to ensure instrument stabilization.

2.3.2 Soak - 6 Minutes

The 6 minute soak procedure is performed as follows. After the completion of the preceding test, the vehicle engine is stopped, the vehicle hood is closed if it was open, and the auxiliary air cooling fan is turned on if it was not previously in use. The fan remains in operation for three (3) minutes. At the end of 3 minutes, the auxiliary air fan is turned off and the vehicle's engine is started. The engine is allowed to idle in neutral for three (3) minutes. Upon the completion of this 3-minute idle period, the next test in the sequence is initiated.

2.4 TEST DESCRIPTIONS

2.4.1 Federal Test Procedure

The Federal Test Procedure is performed as described in Federal Register, Volume 37, Number 221, Section 85.075-9 through 85.075-26 (evaporative emissions testing is excluded). Vehicle preconditioning for vehicles 4101 to 4150 consisted of one short test sequence as described in 2.3.1, or, for vehicles 4151 to 4170, an initial LA-4 driving cycle. In addition to the bag emissions data taken during the FTP, continuous trace data was recorded for HC, CO, CO_2 and NO_x.

2.4.2 Clayton Key Mode

This short test consists of three steady state operating conditions, as described below, from which exhaust samples are taken by the volumetric procedure. HC and CO values are obtained using a Horiba Instruments GSM 300; and NO values are obtained from the continuous trace information. The vehicle is operated in each mode until the exhaust emissions stabilize. The vehicle hood is closed and the auxiliary cooling fan is not in operation while conducting this test.

For this class of vehicle (5000 lb):

Transmission Range	Dyno Load hp @ mph	High Speed Cruise mph	Low Speed Cruise mph	Idle
Drive	30 @ 50	48 to 50	32 to 35	Automatic Transmission in Drive

2.4.3 Federal Three Mode

This short test consists of three steady state operating modes (similar to Clayton Key Mode) with the dynamometer loads simulating the average power which occurs at the appropriate speed on the FTP. Emissions are measured by the volumetric procedure for each mode as described for the Key Mode Test. The vehicle is operated in each mode until the emissions stabilize with the hood closed and no auxiliary cooling fan in use.

For this class of vehicle (5000 lb):

Transmission Range	High Speed Mode		Low Speed Mode		Idle Mode
	Speed mph	Load hp	Speed mph	Load hp	
Drive	50	36	30	18	Automatic Transmission in Neutral

2.4.4 High-Speed Unloaded Test

HC, CO and NO exhaust emissions are measured by the volumetric procedure at an engine speed of 2500 rpm with the transmission in neutral. The vehicle is operated in this mode until the emissions stabilize. The vehicle hood is closed and there is no auxiliary cooling fan in use while conducting this test.

2.4.5 Federal Short-Cycle

This is a 9-mode, CVS test of 125 seconds duration which follows the driving schedule shown below:

Mode	Time in Mode (seconds)
0 - 16 mph acceleration	6
16 - 29 mph acceleration	23
29 mph cruise	10
29 - 37 mph acceleration	18
37 - 42 mph acceleration	4.5
42 - 37 mph deceleration	2.5
37 - 20 mph deceleration	32
20 - 0 mph deceleration	7.5
idle	21.5
	125.0 seconds total

The dynamometer loadings and transmission shift points follow the procedure as required for the FTP.

During the performance of the Federal Short Cycle, the vehicle hood is closed and the auxiliary cooling fan is not in operation.

2.4.6 Composite of N.J. ACID Test and N.Y. Short Test

This is a six mode, CVS test of 75 seconds duration which follows the driving cycle shown below:

During the performance of the Federal Short Cycle, the vehicle hood is closed and the auxiliary cooling fan is not to in operation.

2.4.6 Composite of N.J. ACID Test and N.Y. Short Test

This is a six mode, CVS test of 75 seconds duration which follows the driving cycle shown below:

Mode	Time in Mode (seconds)
Idle	22
0 - 30 mph acceleration	15
30 mph cruise	15
30 - 10 mph deceleration	12
10 mph cruise	7
10 - 0 mph deceleration	4
	75 seconds total

All vehicles are tested at an inertia weight of 3000 lb. and 3.5 hp @ 30 mph. This test is performed with the vehicle hood closed and without the use of an auxiliary air cooling fan.

2.4.7 Defect Tests

Permission was obtained from Ford Motor Company to simulate an engine defect. The following test procedure was used on five (5) vehicles.

Ignition failure on one cylinder (the same for each vehicle) was simulated for thirty (30) seconds at idle,

in drive, while tailpipe emissions were sampled. Samples were also taken by repeating the test with the probe inserted ahead of the catalyst at existing sample points.

HC, CO and NO were recorded as continuous traces on strip charts during the running of these tests.

For the first vehicle tested, the defect was simulated until emission levels stabilized. The Project Officer was notified of the results on this first vehicle as soon as it was completed. The test results are shown in Tabel 2-1.

2.5 PROCEDURAL PRECAUTIONS

2.5.1 Dynamometer Warm Up

If the dynamometer had not been operated during the two-hour period immediately preceding the test, it was warmed up for 15 minutes by operating it at 30 mph using a non-test vehicle. A non-test vehicle is defined as a vehicle not scheduled for any emission test in the following 12 hours.

2.5.2 Pedal Operation

All operation of the accelerator and brake pedals was accomplished with the right foot only.

2.5.3 Invalid Tests

Departure from the driver's trace beyond the limits allowed normally causes an invalid test. Those departures which were generally due to malfunctioning vehicles were immediately noted on the trace itself. Those few departures that were due to driver error were repeated.

Table 2-1 DEFECT TEST RESULTS

Vehicle No.	RPM	BEFORE CATALYST			AT TAIL PIPE		
		HC, ppm	CO, %	NO, ppm	HC, ppm	CO, %	NO, ppm
T2464135	630	2000	0.20	65	750	0.05	92
T0564137	600	1470	0.05	79	630	0.04	160
T1624138	650	1240	0.16	133	620	0.05	214
T0994139	640	1800	0.06	52	650	0.04	79
T0914147	700	1120	0.07	133	230	0.04	146

Section 3

TEST EQUIPMENT

3.1 MAJOR EQUIPMENT

Hydrocarbon (HC) measurements were made by flame ionization instrumentation (FID), carbon monoxide (CO) and carbon dioxide (CO_2) by NDIR instrumentation, and nitrogen oxides (NO_x) measurement by the chemiluminescence (CL) method. The following major equipment was used:

- Horiba FID-2A Flame Ionization Analyzer using 40% H_2 - 60% N_2 fuel with the following full-scale ranges:

0 - 100 ppm	Carbon
0 - 300 ppm	Carbon

- Beckman 108A Flame Ionization Analyzer using 40% H_2 - 60% N_2 fuel with the following full-scale ranges:

0 - 1000 ppm	Carbon
0 - 3000 ppm	Carbon

- Horiba AIA-21 NDIR carbon monoxide analyzer with a full scale range of 0-750 ppm.

- Horiba AIA-2 NDIR Analyzers with the following full-scale ranges:

Carbon Monoxide	0 - 0.3%
Carbon Monoxide	0 - 3%
Carbon Monoxide	0 - 5%
Carbon Dioxide	0 - 10%
Carbon Dioxide	0 - 15%

- TECO NO Analyzer of the chemiluminescence type. This analyzer incorporates a thermal converter for the conversion of nitrogen dioxide (NO_2) to nitric oxide (NO). The NO analyzer full-scale ranges are as follows:

0 - 100 ppm	NO
0 - 250 ppm	NO
0 - 1000 ppm	NO
0 - 2500 ppm	NO

The operating ranges specified for the above sampling conditions and analytical system(s) were expected to cover the concentrations encountered in the performance of this program. In some cases, the undiluted continuous trace data for NO exceeded 2500 ppm.

Since no higher range existed, a common value of 100 plus 0.5 deflections was used to signify a 100-plus trace reading. For vehicles 1-50, that number was 2442; and for vehicles 51 and above, that number was 2444 due to recalibration.

A 0-10,000 ppm NO range was added for the tests occurring after 22 January. Test results exceeding the 0-2500 ppm range were switched to the higher range to obtain actual values.

The Constant Volume Sampler (CVS) conforms to the specifications listed in 37 Federal Register 221 (Section

85.073-20).

The Laminar Flow Element (Meriam Model 50 MC 2-4) was used for calibration of the CVS.

The instrument used for measurement of undiluted HC and CO emissions is a Horiba Instruments, GSM 300. This portable, repair-garage-type instrument is capable of measuring hydrocarbons in ranges of 0-400 ppm and 0 - 2000 ppm Carbon and carbon monoxide in concentration ranges of 0 to 2 percent and 0 to 10 percent.

The dynamometer used is a Clayton Variable Inertia Flywheel Dynamometer with 250-pound increment inertia loading weights (below 3000 pounds inertia weight) and road-loading characteristics. This dynamometer is suitable for use in emission testing up to 5500 pounds inertia weight.

Continuous trace data were collected for HC, CO, CO_2, and NO. The recorders used were Honeywell Electronik 194, two-pen recorders. The following chart speeds were used:

6 inches per minute for all volumetric measurements, including continuous FTP traces for vehicles 4101 to 4150

3 inches per minute for FTP mass measurements from the bag samples and for continuous FTP traces for vehicles 4151 to 4170

6 inches per minute for Federal Short-Cycle and Composite NJ/NY mass measurements for vehicles 4101 to 4170

3.2 CALIBRATION

Analyzers, constant volume sampler, dynamometer calibration gases, and capabilities of personnel were qualified to the satisfaction of the Project Officer prior to the start of the vehicle testing. Calibration curves for the exhaust analyzers, were checked on a monthly basis with zero and span checks made prior to the analysis of each sample. A NO_x converter efficiency check was made weekly. The CVS was checked daily utilizing the Propane Injection Test. The dynamometer calibration was checked monthly.

Calibration gases used in the performance of this contract were delivered to the EPA Laboratories in Ann Arbor, Michigan, within two weeks after contract award date. EPA provided some of the gases through the Propulsion Systems Division of the U.S. Army Tank-Automotive Command and performed the actual analysis on all gases. Olson provided the remainder of the gases as well as providing for their shipment to and from the EPA facilities. These named gases were received by Olson on August 26.

Not all of the required ranges were shipped; and some of the Army gases, not named by EPA due to time constraints prior to shipment to Olson, had a range of concentration values identified instead of a specific value. These unnamed gases were not used. For hydrocarbon calibration, propane concentration rather than methane equivalent concentration resulted in a shortage of low-concentration named gases.

It was found in the course of calibrating the instruments that several of the required gases were apparently either not named correctly or were blended in an unstable mixture. Renaming the gases against a valid curve did not provide the value given on the bottle within a reasonable error. These gases were not used. With the

concurrence of the Project Officer, a combination of the latest EPA named gases and previously EPA named (October 1973) laboratory standard gases (2 percent) were used to enable completion of the calibrations.

The HC, CO, CO_2, and NO_x instruments were calibrated against these gaseous standards. Each CO and CO_2 instrument was calibrated with at least five (5) points spread somewhat evenly across each range.

Calibration of the FID and the CL analyzer was with at least three (3) points across each range.

Calibration was within one percent of full-scale or five percent of measured value, whichever was smaller. Two exceptions, both accepted by the Project Officer, were:

Analyzer	Range	Deflection	Error
CO	0-750 ppm	20.0	5.440%
CO	0-3.0%	11.3	5.077%

The initial calibrations were completed on September 8.

Samples of data forms used for analyzer curve generation, CVS and mass bench propane injection tests, and daily start-up check sheets for mass and volumetric benches are give in Figures 3-1 to 3-4 respectively.

A calibration check was performed on October 7, 1974, on the analyzers and ranges used in the previous month. The 0 to 15 percent CO_2 was found to deviate more than 5 percent from its previously calibrated values in the lower half of the curve. This portion had not been used to date, so a new curve was not generated. The data for this pollutant and range is not specifically reported, but is recorded on a continuous trace for volumetric tests. The dynamometer calibration was checked. Recalibration of the CVS was not found to be necessary.

ANALYZER CURVE GENERATION DATA

DEPT. NO. _____ TRAIN _____ DATE _____ PIC _____

ANALYZER _____ RANGE _____

PURPOSE _____

MAKE _____ MODEL _____ SERIAL NO. _____

DETECTOR NO. _____ CELL LENGTH _____ RANGE SELECT _____

ANALYZER DATA: TUNE _____ GAIN _____ ZERO _____

FLOW RATES (Sample, By-pass, etc) _____

_____

OTHER PARAMETERS (Sample, Oxygen, Air, Fuel-pressure) _____

_____

CURVE DATA: Deflection = [Recorder ☐
[DVM ☐

Zero Gas = [Zero Air ☐
[Nitrogen ☐

Cylinder Zero Gas	Type	Concentration 0.00	Deflection 0.0	Comp. No. 0

Computer Information: Data Tables Changed Y__ N__ ; Curve Fit Method _____

Strip Charts Attached ☐ Data Tables Attached ☐

Comments: _____

_____

_____

_____

_____

Figure 3-1

PROPANE INJECTION TEST

Date:_____ CVS Frame #_____ PIP_____

Train #_____ Dept. #_____ Time_____ AM PM

I. Calculation of V_{mix} (Total Volume of Mixture)

A. P_B = Barom. Pres. = _____ In. Hg x 25.4 = _____mm Hg

B. P_I = Pump Inlet Dpr = _____ In. H_2O x 1.868 = _____mm Hg

C. P_p = Pump Inlet Pres. = $P_B - P_I$ = _____mm Hg

D. P_O = Pump Outlet Pres. = _____In. H_2O ΔP = _____In. H_2O

E. T_p = Pump Inlet Temp. = _____^oF + 460^oF = _____^oR

F. $P_p \div T_p$ = _____

G. N = Pump Revs = _____ Time = _____min; RPM = _____

H. V_O = Pump Vol. per Rev = _____ft 3/rev

I. $V_{mix} = \frac{P_p}{T_p} \times N \times V_O \times .69474$ = _____ft^3

II. A. Weight Exp. B. Bag Analysis

Cylinder (gms)	Bag	Deflection	Range	Concentration (ppm)
Before = _____	Sample_____		____	_____
After = _____	Bkgd_____		____	_____
Δ = _____			Conc =	_____

III. Mass Calculation (Mass = $V_{mix} \times 17.3 \times Conc \times 10^{-6}$)

Mass = _____gms

$$\text{Error} = \frac{\Delta\text{-Mass}}{\Delta} \times 100 = _____\,\%\ \text{H}\ /\ \%\ \text{L}$$

COMMENTS:_____

_____

_____

_____

_____

_____

QC Use
Approved_____
Rejected_____
By_____

Figure 3-2

OLSON LABORATORIES, INC.

TESTING SERVICES DIVISION

MASS START-UP CHECK SHEET

DEPT NO.	SHIFT	TRAIN	DATE	P.I.C.	WEEKLY	DAILY

CALIBRATION

	HIGH								INTERMEDIATE						
	RNG	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	TUNE	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	MFGRS MODEL NO.
CO	0.3														
	3.0														
FIA	500														
	1K														
	4K														
NO_X	250														
	1K														
CO_2	4.0														
ZERO															

RECORDER				PRESSURE					BYPASS	CONV	REACTOR	LEAK CHECK				
CHART SP	ZERO	GAIN	DVM CORR		SAMPLE	FUEL	AIR	OZONE	FLOW RT	IND TEMP	OPR PRESS.		FIA	CO	CO_2	NO_X
				FIA								FL MTR OBS				
				NO_X						°C	MM	MAG OBS				

CVS

1 MIN. COUNT	N. PRESS.	OUT. PRESS.	T.P. PRESS.	VOL REV	FLEX	ADAP	BAGS	LIGHTS	PUMPS	SWITCHES	TEMP CONTROL

COMMENTS

FL JM GC 02 1 FEB 72 WHITE/SITE FILE CANARY/QUALITY CONTROL PINK/REGIONAL MANAGER

Figure 3-3 3-8

OLSON LABORATORIES, INC.

TESTING SERVICES DIVISION

7-MODE START-UP CHECK SHEET

DEPT NO.	SHIFT	TRAIN	DATE	P.I.C.	WEEKLY	DAILY

CALIBRATION

		HIGH							INTERMEDIATE							
	RNG	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	TUNE	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	MFGRS MODEL NO.
CO	0.3														
	10														
FIA															
	1K														
	3K														
NO_X	1K														
	2.5K														
CO_2	15														
ZERO															

RECORDER				PRESSURE						BYPASS	CONV	REACTOR	LEAK CHECK				
CHART SP	ZERO	GAIN	DVM CORR		SAMPLE	FUEL	AIR	OZONE		FLOW RT	IND TEMP	OPR PRESS.		FIA	CO	CO_2	NO_X
				FIA									FL MTR OBS				
				NO_X							°C	MM	MAG OBS				

COMMENTS _____

FORM QC 02 1 FEB 72 WHITE/SITE FILE CANARY/QUALITY CONTROL PINK/REGIONAL MANAGER

Figure 3-4

Recalibration of all instruments and ranges initially calibrated was completed by November 8, with the exception of the GSM 300 which was checked on November 26.

The 0 to 4 percent CO_2 instrument was found to have drifted, with the major drift on the lower end of the scale. Checking the day-to-day lab data showed that the instrument problem occurred subsequent to November 1 and therefore did not affect any of the tests for this project. All other curves (excepting the 0 to 15 percent CO_2 previously noted) were found to be acceptable, including the dynamometer and CVS.

The appropriate calibration gases were prepared for return to the Army, but a hold was put on the shipment until disposition of the five catalyst vehicles stored at Olson is resolved.

Prior to testing the ten additional vehicles requested by the Project Officer in December, the following instruments and ranges were recalibrated.

Analyzer	Range	New Curve
Mass Bench		
HC	0-100 ppm	Yes
CO	0-750 ppm	Yes
CO_2	0-4%	Yes
NO_x	0-100 ppm	Yes
NO_x	0-250 ppm	No
Volumetric Bench		
HC	0-1000 ppm	No
CO	0-3000 ppm	No
CO_2	0-15%	Yes
NO_x	0-2500 ppm	Yes

The dynamometer had been recalibrated on November 25, so this new curve was used. The CVS calibration was checked and found to be satisfactory.

All instruments were calibrated prior to commencing the group of tests initiated in January. A new mass bench had been installed in the interim between the December and January tests requiring complete calibration. In addition, the EPA/Army calibration gases used in earlier calibrations had been prepared for return to the Army so new calibration gases were utilized. The gases used were "Golden Standard" gases obtained from the EPA/Olson surveillance test program at Levittown, PA. The dynamometer was recalibrated on January 13 and on February 8. A new CVS calibration was performed on February 12.

Analyzer calibration curve points, CVS calibration and dynamometer calibration curve point tables are presented in Appendices C, D and E respectively.

Section 4

DATA PREPARATION

Test data were entered on punched, interpreted cards (except driver traces) in a format approved by the Project Officer shortly after contract award. Maintenance data were obtained from Ford Motor Company for summarization and presentation to EPA.

4.1 TEST DATA

Vehicle information consists of basic parameters such as vehicle program identification number, make, model year, accummulated mileage, date(s) of test(s), engine displacement, carburction, transmission type, emission control systems on the vehicle, inertia weight, horsepower settings, license number, owner identification, VIN, engine parameter settings and identification of control systems either inoperative or functioning improperly. (See Figure 2-1.)

Exhaust emission test results include ambient temperature, barometric pressure, humidity, mass emissions in each bag from the FTP and each CVS sampled short test, and concentration emissions from each mode for all other short tests. (See Figures 2-2 and 2-3.) NO_x is reported as NO_2 both as measured and corrected for relative humidity. The humidity correction factor was calculated from a method provided by EPA dated March 8, 1974.

Grams-per-mile emissions for the FTP were calculated per the Federal Register, Volume 37, Number 221, Section 85.075-26.

Mass emissions for the Federal Short Cycle test were computed by the following formula:

$$m = Vdc/a$$

where:

m = mass emissions in grams per mile

V = total CVS flow = Volume per revolution times revolution count

d = density of the exhaust component

c = measured concentration in the bag less the background concentration

a = cycle length in miles (0.7536)

Running two tests back-to-back for vehicles 4151-4170 resulted in twice the revolution count for twice the cycle length. These factors of two cancel in the equation.

Measured concentration values for the composite NJ/NY test are reported, but mass emissions were not computed.

Fuel usage, in miles per gallon, was calculated from bag data according to the carbon balance technique and reported for each FTP on each vehicle.

All data were transmitted to EPA for statistical analysis upon completion of an error screening process and computer run. This submittal was made on the Friday of the week following actual testing. Each submittal included all emissions strip charts, the driver's trace, CVS temperature

trace, computer summary printout for all tests for that week, and the test data on punched 80-column computer cards.

4.2 REPORTS

Weekly Reports - Data were reported on punched, interpreted and verified cards. Cards, strip charts and computer printouts covering each week's work were sent to the Task Project Officer by the Friday of the following week.

Weekly progress reports were made by telephone to the Task Project Officer or his representative during the morning of the last day of the business week (normally Friday).

Monthly Reports - Olson furnished letter-type monthly reports to the Task Project Officer and one copy to the Contracting Officer by the fifteenth of the month following the month being reported on. These reports outlined the progress made, together with slippages and procedures for correction, manpower expenditures (including names of personnel and their classification, e.g., John Doe, Driver) and costs for the month and the total contract on milestone charts. In conjunction with the letter reports, one copy of EPA Form 1900-11 was submitted to the Contracting Office and one copy to the Task Project Officer.

4.3 VEHICLE USE AND MAINTENANCE HISTORY

A use-and-maintenance history was obtained from Ford Motor Company records for each of the first 60 vehicles tested. It was not always possible to identify who actually performed the maintenance. Reasonable assumptions were made based upon the total information in each maintenance

package and the area of vehicle usage.

Maintenance histories were not available for all of the vehicles tested in January and February (but see page 1-3) due to transfer of the catalyst Task Force to Dearborn, Michigan.

4.3.1 Vehicle Use

The primary usage areas for the tested vehicles (all in California) were:

Location	Total Number of Vehicles
Fresno	2
Goldstone (Barstow)	16+1 San Diego
Sacramento	27
San Diego	9
San Francisco	3
San Luis Obispo	3
	60

The following paragraphs describe the general type of use to which the vehicles assigned to each of these locations were subjected.

Fresno - These vehicles were used by State of California personnel from a limited pool. They were driven over all types of roads with many trips to other districts, especially Sacramento. One vehicle was assigned to a specific person.

Goldstone (Barstow) - These vehicles are used by NASA personnel for transport from Barstow to the Goldstone Tracking Facility. The distance is approximately 53 miles each way over dry desert at very high speeds. A small

amount of stop-and-go driving was involved to pick up or drop off five passengers (about seven miles). One vehicle was used in San Diego and then at Goldstone.

Sacramento - State and Federal employees used these which were drown from a motor pool. Many different drivers and all types od driving conditions were involved, especially stop-and-go. One vehicle was used in Bishop.

San Diego - These vehicles had limited use by State employees from a pool and were used mostly for local driving. Two vehicles were each assigned to specific persons. One vehicle was later transferred to Goldstone.

San Francisco - These vehicles were part of a central motor pool and were used for all types of driving; mostly by VIPs.

San Luis Obispo - State employees had use of these vehicles from a limited pool for driving over all types of roads with many trips to other districts, including Sacramento.

4.3.2 Vehicle Maintenance

Control vehicles that were included in the sample were maintained primarily at 12,000 mile intervals by Ford at Pico Rivera when emissions tests were scheduled. Oil change and non-emissions related maintenance was mostly performed by Ford dealers or by motor pool personnel.

Non-control vehicles were maintained by motor pool personnel at Goldstone and by Ford dealers at other locations following procedures established and monitored by Ford Motor Company. Particularly difficult problems were handled by Ford at Pico Rivera.

Table 4-1 presents a list of the required maintenance actions for all catalyst fleet vehicles. Table 4-2 is a summary of the required actions performed on the 60 vehicles acquired by Olson. A complete tabulation of scheduled and unscheduled emissions related maintenance performed on each tested vehicle, with mileage and dates performed, is included in Appendix F.

Table 4-1 REQUIRED SERVICE INTERVALS

1,000 Miles or Months, Whichever Occurs First

	4/4	8/8	12/12	16/16	20/20	24/24	28/28	32/32	36/36	40/40	44/44	48/48
. Check coolant strength and inspect cooling system. If the coolant is dirty and rusty in appearance, the system should be cleaned and flushed. Clean the radiator cap.			X						X			
. Inspect the cooling system hoses for deterioration, leaks, and/or loose hose clamps. Repair or replace as required.						X						X
. Drain and flush the cooling system. Replace coolant mixture.						X				(Time Basis Only)		X
. Check distributor cap and rotor.						X						X
. Inspect evaporative emission control canister and purge hose.						X						X
. Test engine compression - all cylinders. Repair any cylinder below specification (mileage basis only). When checking compression, take the highest compression reading and compare it to the lowest reading. The lowest reading must be within 75% of the highest.						X			X			

Table 4-1 (cont.) REQUIRED SEIVCE INTERVALS

1,000 Miles or Months, Whichever Occurs First

	4/4	8/8	12/12	16/16	20/20	24/24	28/28	32/32	36/36	40/40	44/44	48/48
. Clean crankcase breather cap.			X			X			X			X
. Replace spark plugs and set gap.			X			X			X			X
. Check and adjust initial ignition timing -- 12° B.T.D.C.			X			X			X			X
. Check distributor points and set gap. Inspect condenser for loose terminals and/or ground connections.			X						X			
. Replace distributor points. Dwell 24° - 30°.						X						X
. Check secondary ignition wires resistance; inspect wires for cuts, burns, abrasions, or punctures.			X			X			X			X
. Inspect all spark control system vacuum hoses and electrical leads for damage, deterioration and firm connections to proper points.			X			X			X			X
. Check for correct spark control system advance			X			X			X			X
. Check for distributor spark advance and adjust if necessary						X						X
. Replace spark delay valves			X			X			X			X
. Check for correct component assembly and functioning of air cleaner intake temperature control system.			X			X			X			X
. Replace PCV valve, clean emission system hoses, tubes. Replace if deteriorated.			X			X			X			X

Table 4--1 (cont.) REQUIRED SERIVCE INTERVALS

1,000 Miles or Months, Whichever Occurs First

	4/4	8/8	12/12	16/16	20/20	24/24	28/28	32/32	36/36	40/40	44/44	48/48
. Change engine oil. (Must meet Ford Specification ESE-M2C101-C/SE)	X	X	X	X	X	X	X	X	X	X	X	X
. Change engine oil filter. (Must meet Ford Specification C8AF-6714-A or C)	X		X		X		X		X		X	
. Check and adjust carburetor, curb idle speed, fast idle speed, and throttle solenoid off-speed.			X			X			X			X
. Torque intake manifold bolts to specification.						X						X
. Replace crankcase emission filter in air cleaner.		X		X		X		X		X		X
. Replace carburetor air cleaner filter element.			X			X			X			X
. Inspect fuel evaporative emission control system for restrictions or damage to filler cap, fuel vapor line and fuel tank. Repair or replace as required.			X			X			X			X
. Check operation of carburetor throttle and choke linkage, and air valve, dashpot, and throttle solenoid. Lubricate, adjust, or repair as required. Curb idle, 650 RPM -- fast idle, 1500 RPM.			X			X			X			X
. Replace fuel system filter and check fuel lines and connections for leaks.			X			X			X			X
. Check the EGR system for function. Inspect and clean the EGR valve and system. Clean the exhaust passages in the carburetor spacer and intake manifold (8 cylinders). Repair or replace as required.			X			X			X			X
. Check accessory drive belts for tension and wear and adjust or replace as required.			X			X			X			X

Table 4-2 SCHEDULED MAINTENANCE ACTIONS

Vehicle No.	Mileage As Received	Location	Scheduled Maintenance Intervals 4K	8K	12K	16K	20K	24K	28K	32K	36K
T0284101	15,168	Sacramento	x	x	x						
T1894102	6,655	San Francisco	x	x							
T2433103	15,199	Sacramento	x	x	x						
T0484104	6,987	San Francisco	x	x							
T0234105	17,596	Goldstone	x	x	x	x					
T2044106	18,978	Goldstone	x	x	x	x					
T2714107	15,156	Sacramento	x	x	x						
T2754108	14,139	Sacramento	x	x	x						
T3304109	24,063	Fresno	x	x	x	x		x			
T3104110	21,623	San Luis Obispo	x		x	x	x	x			
T1064111	17,261	Goldstone			x						
T0974112	21,754	Goldstone	x	x	x	x	x				
T1764113	11,240	Sacramento	x	x							
T1274114	21,848	Goldstone	x	x	x		x				
T3044115	18,571	San Diego			x						
T1714116	20,917	Sacramento	x	x	x	x	x				
T2194117	10,258	Sacramento	x	x							
T0264118	8,740	San Francisco	x	x							
T3494119	18,320	San Diego			x						
T3434120	16,566	San Diego			x						
T3414121	19,869	San Diego		x	x						
T1644122	19,761	Goldstone	x	x	x	x					
T3234123	18,614	San Diego			x						
T3124124	17,257	San Diego			x						
T2774125	22,697	Goldstone	x	x	x	x	x				
T2894126	16,701	Sacramento	x	x	x	x					
T2984127	12,649	Sacramento	x	x							
T2974128	9,228	Sacramento	x	x							
T2574129	10,154	Sacramento		x							
T2674130	9,204	Sacramento	x	x							

Table 4-2. SCHEDULED MAINTENANCE ACTIONS (cont.)

Vehicle No.	Mileage As Received	Location	Scheduled Maintenance Intervals 4K	8K	12K	16K	20K	24K	28K	32K	36K
T3294131	20,019	San Diego			x						
T1814132	20,615	Goldstone	x	x	x	x	x				
T2804133	9,401	Sacramento		x							
T0654134	18,104	Goldstone	x	x	x	x					
T2464135	15,660	Sacramento	x	x	x						
T1004136	20,644	Goldstone	x	x	x	x					
T0564137	20,583	Goldstone	x	x	x	x					
T1624138	16,074	Sacramento	x	x	x						
T0994139	20,981	Goldstone	x	x	x						
T2844140	16,264	Sacramento	x	x	x	x					
T2544141	Untested*	Sacramento	x	x							
T2364142	9,857	Sacramento	x	x							
T2494143	14,646	Sacramento	x		x						
T1614144	25,005	Sacramento	x	x	x	x	x	x			
T2624145	10,975	Sacramento									
T3394146	14,078	San Diego			x						
T0914147	17,071	Goldstone	x	x	x						
T3004148	7,538	Sacramento									
T1754149	Untested*	Sacramento		x							
T2104150	23,172	Sacramento	x	x	x	x					
T0534151	35,388	San Diego and Goldstone	x	x	x	x	x	x	x	x	x
T3784152	33,209	Fresno	x		x			x			x
T1194153	34,689	Goldstone	x	x	x	x	x	x	x	x	x
T3734154	35,615	Sacramento and Bishop	x		x			x			x
T3364155	36,025	Sacramento	x		x			x			x
T1204156	34,310	Goldstone	x	x	x	x	x	x	x	x	x
T1234157	34,274	Goldstone	x	x	x	x	x	x	x		x
T3244158	32,743	San Luis Obispo	x	x	x	x	x	x		x	x
T3594159	35,875	Sacramento	x		x			x			x
T3074160	33,509	San Luis Obispo	x	x	x	x	x	x		x	x

* Tested with January group.

4.3.3 Component Retrofit

Three ignition items were retrofitted on nearly every car tested. These retrofits were performed at various mileage points in the life of each vehicle. The specific item replaced, date and mileage are included in the complete maintenance listing given in Appendix F. The installer completing each retrofit is also identified whenever possible.

Ignition Points - The original equipment point sets were replaced on all but one tested vehicle with a new design. The rubbing block on the original design showed some susceptibility to breakage.

Cold Wire - The original primary coil wire was replaced on most vehicles with a design that allowed easy attachment of a tachometer for periodic engine parameter inspection. The previous design tended to break after repeated removal to allow tachometer connection.

Spark Plug Wires - The wire set was replaced on a number of vehicles with a set of solid wire cables instead of the carbon impregnated type which were found to break down quite often. Sixteen out of the 60 vehicles experienced failure of one or more plug wires, reguiring replacement.

A coolant recovery system was also retrofitted on many of the vehicles to ensure that overheating did not occur due to loss of radiator coolant. These recovery kits were installed on any of the vehicles that showed any tendency to overheat. Twenty-six of the vehicles were retrofitted and are noted in Appendix F.

4.3.4 Additives and Misfuels

Table 4-3 lists the vehicles that were misfueled with leaded gas and that received gasoline or oil additives

Table 4-3 MISFUELS AND ADDITIVES

Vehicle No.	Mileage	Date	Misfuel	Gas Additive	Oil Additive
T0284101	5,800	10/29/73	x		
T0234105	1,317	8/21/73	x		
	7,000	11/23/73	x		
T2714107	4,000	8/10/73			x
	8,169	9/01/73			x
	-	2/27/74	x		
T3304109	7,986	9/24/73	x		
	20,453	5/10/74	x		
T3104110	4,625	7/31/73	x		
T2984127	7,753	11/09/73			x
T2464135	13,565	3/14/74			x
T2544141	8,170	3/13/74			x
T2494143	11,828	3/26/74		x	
T1614144	4,083	9/05/73	x		
T0534151	4,127	9/14/73	x		
T1194153	1,307	7/25/73	x		
T3364155	8,806	10/05/73	x		
T3244158	1,813	5/23/74	x		
	16,245	1/09/74	x		
T3584159	11,991	11/20/73	x		
	15,632	3/18/74	x		
T3074160	11,762	11/14/74	x		

during their mileage accumulation. Vehicles that were accidentally misfueled were generally not driven prior to draining and flushing the tank with unleaded fuel.

Several of the vehicles were retrofitted after July 1974 with the small gas tank filler neck provided on 1975 vehicles to guard against misfueling.